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Allocation of effort in artisanal fisheries: The importance of migration and temporary fishing camps

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ABSTRACT

In order to avoid conflicts when spatially explicit rules are implemented, it is critical to understand the spatial distribution of fishing effort, the migration patterns of fishermen and the use of temporary fishing camps. The migration of fishermen is a process shaped by historical patterns of resource availability, in addition to economic and political factors. We present an example in which a temporary fishing camp used for extraction of benthic resources (Loco: *Concholepas concholepas*) changed into a permanent one during the study period. Throughout the study period fishing effort (trips) was closely related to the productivity of the different fishing grounds, with more trips directed to the most productive areas. The conversion from a temporary to a permanent fishing camp did not improve the efficiency of the loco fishery, but did allow better access to alternative resources (surf clams) on nearby fishing grounds. The succession from simple shelters to a permanent 'caleta' is a common situation along the Chilean coast, motivated originally by resource availability and more recently by the creation of the TURF system. In particular the TURF system converts temporary (resource driven) movements of fishermen into rigid stationary caletas, which creates a number of problems. Temporary fishing camps are common when fishing grounds are far from the base port, but they require specific administrative tools in order to achieve sustainable fisheries management.

1. Introduction

1.1. Spatially explicit areas: a growing tendency for fisheries management

Understanding and documenting the spatial distribution of fishing effort, migration patterns of fishermen and the use of temporary fishing camps is important in order to avoid conflicts when spatially explicit rules are implemented. Over the past decade there has been a growing worldwide interest in managing fisheries through spatially explicit policies. The implementation of marine protected areas, exclusion and rotation systems, among others, have acquired a growing importance as a tool in fisheries management [1,2]. However, in order to implement such administrative tools, it is important to consider spatial and temporal dynamics of fishermen and fishing effort [2–6], in conjunction with information about the spatial and temporal distribution of the main resources, as a means to contribute toward the development of more efficient administration policies [7–9].

1.2. Resource variability and its effect on the distribution of fishing effort

Most fisheries analyses focus on biological processes, often ignoring the behavior and decision making processes of fishermen [6], which has been compared to ignoring the predator in the predator–prey relationship [10]. Benthic resources often occur in discrete patches, with variable dynamics and population levels [2,11,12]. The heterogeneous spatial distribution of resources also influences the spatial distribution of fishing effort [13]; if resources are unevenly distributed in a given area, then it can be expected that this will also be the case with the fishing effort. The number of fishermen should be in direct relation to resource availability, and their spatial distribution pattern along the coast is expected to fit the spatial productivity pattern of the resource.

1.3. Social factors also determine spatial distribution of effort

Social or logistical factors (e.g. access to the fishing grounds) can also influence the distribution of effort. Climatic conditions may occasionally cause competition between fishermen over accessible fishing grounds [14]. More importantly, though, rules

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and institutions can restrict the movement of fishermen, closing access to some fishing grounds [3,15]. Consequently, the distribution of fishermen may not necessarily match that of the resource [16].

Short-term decisions of fishermen about how, where and when to catch are related to daily decisions, and predictions about these decisions are critical for the design of regulatory policies [6]. In relation to *where* to fish, safely navigable distances, individual risk aversion and vessel type can influence the decisions of fishermen [13]. A "friction of distance" concept [17] predicts that resources will be exploited more intensively closest to home ports. More distant fishing grounds are thought to have more pristine stocks, and therefore might potentially offer higher catches. In consequence, the decision of *where* to catch is a trade-off between costs and expected higher benefits [3].

1.4. Mobility of fishermen and temporary fishing camps

Moving in search of resources is a common characteristic of many fisheries, in particular those of an artisanal nature. Temporary migration to places where fish are available is a prevalent feature of artisanal fisheries worldwide [18,19]. Temporary fishing camps are frequently set up by fishermen in developing countries, but are seldom addressed in accounts of 'fishing communities' [20]. Migration of fishermen is a process shaped by historical patterns, resource availability, and economic and political factors, rather than simply a reaction to recent human population pressure [18]. Although migrations of fishermen have been described previously, there is a lack of official registers about temporary fishing camps that they use for their operation. This undocumented information obviously complicates interpretation and furthermore is a relevant issue in the design of spatially explicit management tools.

1.5. Chilean artisanal fisheries for benthic resources

In small scale fisheries along the Chilean coast, temporary fishing camps are a common feature. These artisanal fisheries are based on benthic resources and are characterized by an important social component [21]. Small scale fisheries sustain approximately 436 artisanal 'caletas' along the Chilean coast with a total of 13,881 registered divers [22]. Caletas are coastal locations (mainly sheltered coves) that serve as operational bases for local artisanal fleets. In rural areas, caletas are equivalent to fishing villages; in urban areas, fishermen and their families are part of larger communities [23].

Besides official caletas (designated by the Chilean Navy), there are a large number of places that offer favorable conditions (protected bays and road access), which are used as temporary landing sites, a kind of "temporary caleta". These are used by fishermen to leave their boats, or even as a camp site, when they move along the coast in an attempt to reduce navigation distances to more productive fishing grounds, thus improving the efficiency of the fishery. In some cases, these temporary fishing ports may become more permanent and officialized if they are repeatedly and consistently used by fishermen. In fact, many of the present official caletas have arisen from temporary fishing ports in the past (Fig. 1).

One of the most important resources for Chilean benthic artisanal fisheries is the highly valued gastropod *Concholepas concholepas*, locally known as "loco", which in some parts is also exploited from temporary fishing camps. This predatory snail from subtidal rocky habitats (0–30 m water depth) is usually harvested by hookah diving (Fig. 1). Historic catches of the loco had remained relatively stable until the mid 1970s. A very active export policy during the late 1970s, and high prices, caused catches to increase rapidly, from 6000 tons in 1970s reaching 25000 tons in 1980 [24]. These events motivated one of the most important migratory processes of fishermen along the Chilean coast: numerous people were attracted to the fishery and existing caletas increased in size and new caletas were founded.

Due to the intensive extraction, however, catches quickly began to fluctuate and the diagnosis made by Subsecretaría de Pesca (Undersecretary of fisheries, the national governmental department in charge of fisheries) during the late 1980s was that the resource was severely overexploited. Temporary closure of the fishery (from 1989 to 1992), Individual Quota (IQ, from 1993 to 1999) and Territorial User Rights Fishery (TURF, established mainly for loco since 1997) have been introduced as management tools to protect the loco. While the regulations led to a spatial stabilization of fishermen, these continue to adapt to the distribution of the resource, and temporary fishing camps continue to exist both on uninhabited islands and on remote coasts. This obscures official records and can also interfere with spatially explicit management tools such as TURFs.

1.6. Case study – loco fishery in northern-central Chile

In this paper we explore an example from northern-central Chile in the Region of Coquimbo in order to better understand the dynamics of fishing effort in relation to stable caletas and temporary fishing camps. We analyze loco fisheries during the period 1993–1999, when the fishery was regulated by quotas in a regime called Benthic Extraction Regime (BER). During this period, all fishermen were registered in one of the twelve administrative regions of Chile and within (but not beyond) each region fishermen were allowed to migrate freely along the coast. During this period, migrations between caletas did occur within a region. In addition, temporary fishing camps were developed, often by people who already had a good understanding of local conditions (resource availability, oceanography, road access). Herein, we examine a case in one of the most productive zones for loco in northern-central Chile, which was selected because a temporary fishing camp changed into a permanent one during the study period. In particular, we examined whether the establishment of the new caleta changed the loco exploitation pattern of local fishermen along the coast.

2. Methods

2.1. Study area

In order to understand the dynamics of fishing effort, we analyzed the loco fishery in a study area located in northern-central Chile, between Punta Teatinos (29°49'S, 71°18'W) and Punta Choros (29°11'S, 71°30'W) (Fig. 2). We selected this area because it has historically produced the highest landings of loco in northern-central Chile, and because temporary fishing camps have traditionally been used by local fishermen in this locality. Along the study area there are 5 caletas (Fig. 2), one of which (Totoralillo Norte) was formally established during the study period after having been used as a temporary fishing camp for many years.

The study zone extends along 80 km of coast line, mainly comprising rocky shores with different degrees of exposure to wind and waves in the southern half, and a series of sandy beaches in its northern half. The longest sandy beach is called "Playa Los Choros" (Fig. 2). Within navigation distance of the continental coast there are several uninhabited islands, which harbor large populations of seabirds. In the past, fishermen camped on the Choros, Damas and Pájaros island, which at present is prohibited, as these islands are protected for the conservation of seabird breeding stocks.

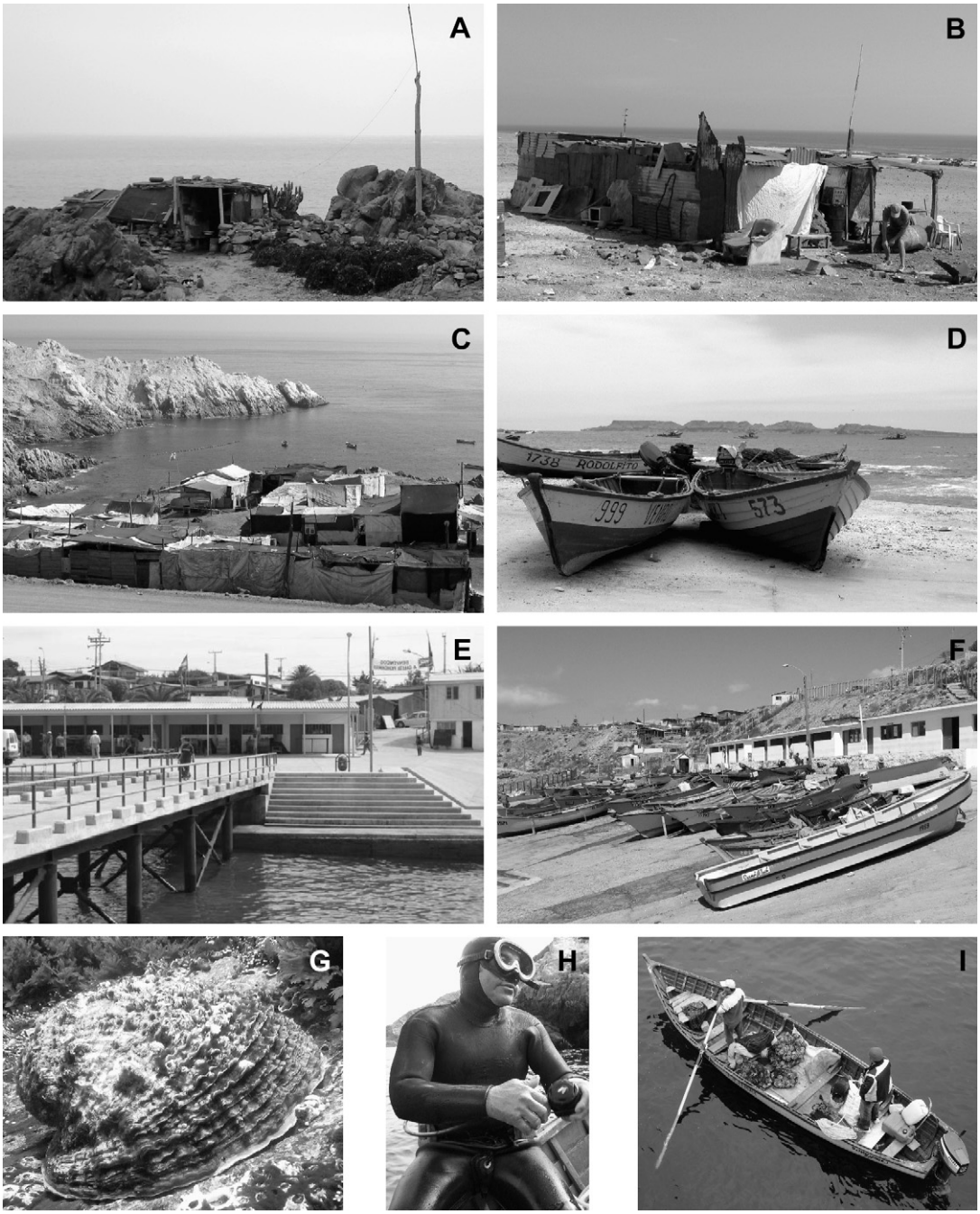

Fig. 1. Fishing camps during early establishment (A), a process of development (B and C), and as permanent and developed caletas (caleta Punta Choros – Isla Choros in background-D, Pichidangui E and caleta Hornos, F). The benthic gastropod *Concholepas concholepas*, or "Loco" (G), Hookah diver for benthic resources (H), and Loco harvest in boat at caleta Chungungo (I).

2.2. Catches of loco from fisheries in the benthic extraction regimes (BER)

For the analyses of fishing effort and efficiency, we utilized a data base from the monitoring of the loco fishery under the BER, i.e. before the implementation of the presently functioning management areas (TURF). From 1993 to 1999, in the BER (with individual quotas, IQ), a port-sampling program was conducted by the Instituto de Fomento Pesquero (IFOP). Port samplers were located at each caleta throughout the entire fishing season, interviewing the crews of all boats when they returned to the base port. Information recorded for each trip included: the identification number of the boat, number and names of divers, catch (in units of loco), duration, fishing location, fishing ground, water depth and diving time. For the purposes of this study, this information was obtained from project FIP 2002-16 "Biological bases for the evaluation and management of the metapopulation of *Concholepas concholepas* in Regions III and IV" [25].

In the study area, 22 different fishing grounds were identified. Within each of these fishing grounds, smaller units were identified, each corresponding to a coastal zone called "fishing areas". The names and locations of each fishing ground in the data base were corroborated by directly asking the fishermen from the study area. Fishing trips were used as the unit for the estimation of the capture

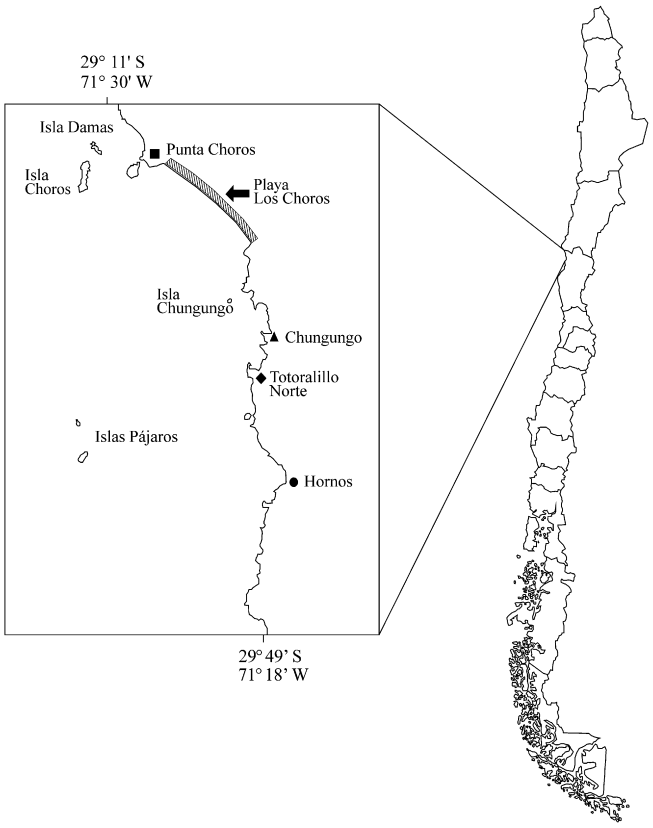

Fig. 2. Study area. Caletas and main fishing grounds on nearby islands are shown. Locos are extracted from subtidal areas of 20 m water depth or less. The 20 m isobath is not shown because in most areas it is very close to the shoreline.

per unit effort (CPUE) index. For graphical analyses, all data were integrated into a Geographic Information System (GIS) data base.

2.3. Data analyses

In order to examine whether the establishment of a new caleta resulted in an improvement in fishing efficiency, data were separated in two periods, from 1993 to 1996, and from 1997 to 1999. This was done because Totoralillo Norte appeared as a new official caleta in the study area for the first time in 1997. To identify the most visited fishing grounds during the BER, the total numbers of fishing trips to each one were analyzed with GIS. A similar analysis was conducted separately for each caleta and for both periods (1993–1996 and 1997–1999) in order to identify the spatial distribution of effort on each fishing ground by fishermen of different caletas and to identify potential changes in the spatial distribution of effort once Totoralillo Norte was designated as a new caleta.

In order to determine if fishermen made more trips to fishing grounds that produced higher catches, we conducted a regressions analysis between the number of fishing trips and catches on the respective fishing grounds for both analyzed periods. Slopes of both periods were compared to determine similarities or differences. For some analyses, data were transformed using $\log_{10}$.

Finally, we examined how fishermen from different caletas allocate fishing effort in relation to the travel distances to the respective fishing grounds. Data were grouped into three distance ranges: <8 km, 8–15 km, and >15 km. The rationale for these categories is that 15 km is the distance that corresponds approximately to one full tank of a normal outboard engine, and is usually the maximum distance that fishermen are able to navigate on a normal fishing day.

3. Results

3.1. Temporal and spatial distribution of catches and fishing effort

Throughout the study period, fishing trips were distributed along the entire rocky coast of the study area (Fig. 3). The majority of fishing trips were concentrated in the northern sector of the study area, specifically in Punta Choros, Isla Choros and Isla Damas. Other important fishing grounds were Isla Pajaros and "Chungungo A", the latter of which is located near caleta Chungungo.

Mean annual catches decreased by 39% from the 1993–1996 period to the 1997–1999 period (see numbers in Fig. 4). Regarding the spatial pattern during both study periods, the highest loco catches were obtained from Punta Choros (Fig. 5) and the main fishing grounds remained the same over time (Fig. 4A and 4B). Other important fishing grounds were Isla Damas, Isla Choros, Chungungo A (close to caleta Chungungo), Islas Pájaros, and two fishing grounds located near caleta Hornos (Figs. 4A and B).

3.2. Relationships between effort and catches over time

Fishermen adjusted their fishing effort (trips) to the different fishing grounds (Figs. 5 and 6), conducting more trips to the most productive areas. Nevertheless this relationship changed significantly between the period 1993–1996 and the period 1997–1999 ($t_{0.05(2),154} = 2.228$; $P < 0.001$). The differences observed in the regression slopes between both periods represent an increase in effort (numbers of trips) during 1997–1999. For both periods, the relationships between trips and catches were significant (1993–1996: $F = {}_{0.05(1),1.84} = 367.2$; $P < 0.001$; 1997–1999: $F = {}_{0.05(1),1.70} = 221.6$; $P < 0.001$).

3.3. Distribution of effort by caletas

For the period 1993–1996, the highest number of fishing trips were made by fishermen from caleta Punta Choros and all were directed to nearby fishing grounds (Fig. 7A). The other two caletas showed a different pattern, with a large proportion of trips to fishing grounds more distant than 8 km from the caleta,

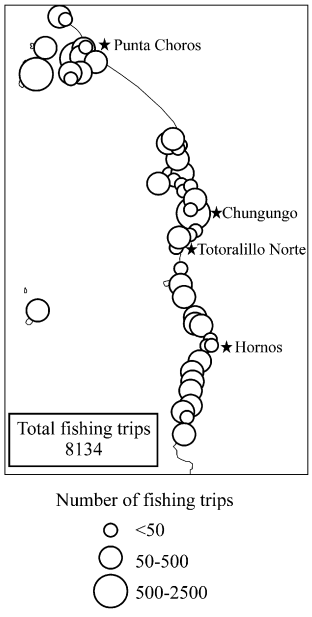

Fig. 3. Effort distribution (total number of fishing trips) in the study area.

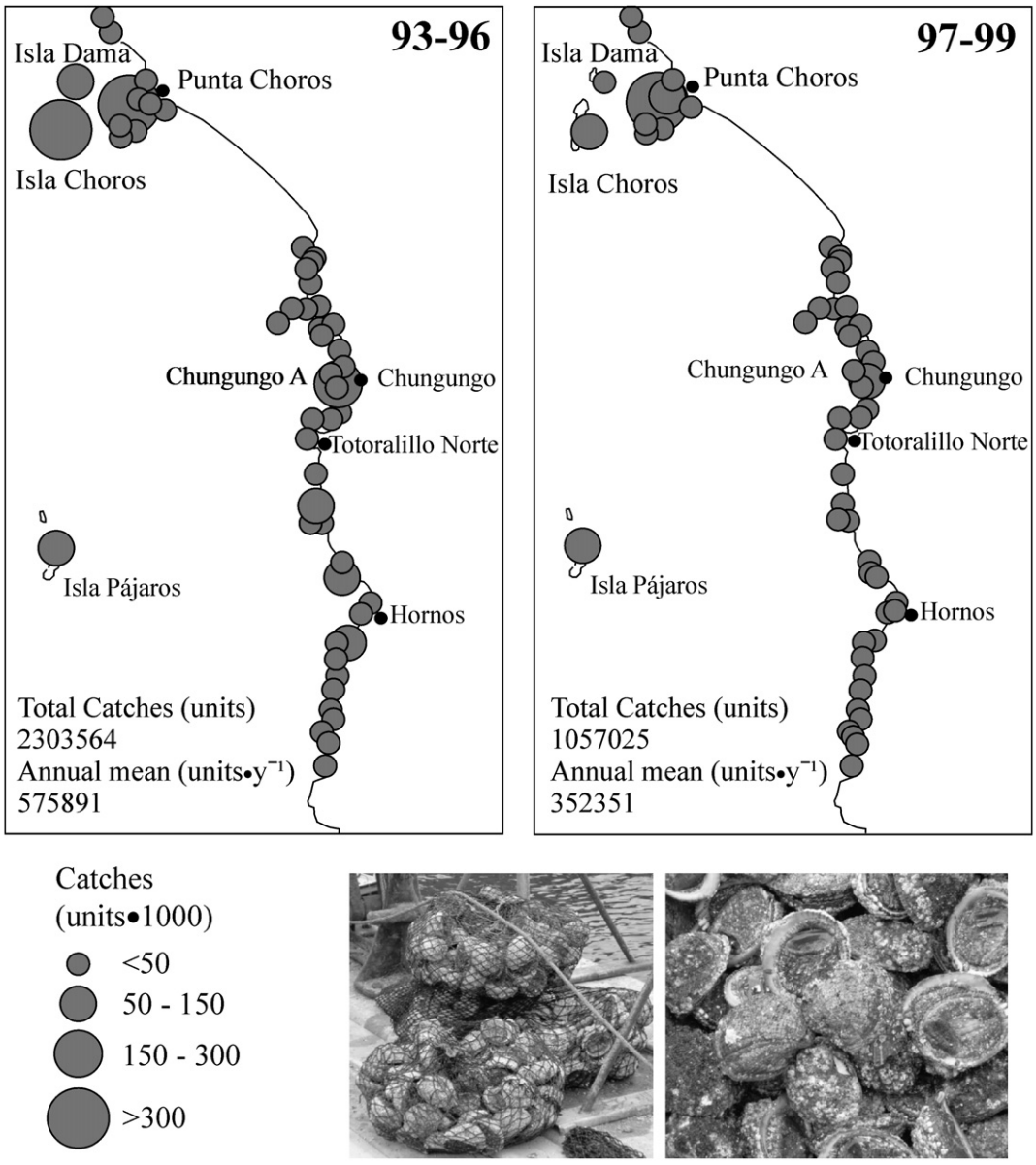

Fig. 4. Spatial distribution of catches in the study area during the periods 1993–1996 and 1997–1999.

especially at caleta Hornos. The high numbers of trips made to more distant fishing grounds is explained by the fact that one of the most productive fishing areas is Islas Pájaros, located 25 km from the coast. For the period 1997–1999, the pattern was similar, and the appearance of Totoralillo Norte as a new caleta caused no changes in the high proportion of fishing trips >8 km from the caletas Chungungo and Hornos (Fig. 7B). Nevertheless, in caleta Hornos there was a decrease in trips to fishing areas close to the caleta (8 km range), accompanied by an increase in trips to fishing grounds at intermediate distances from the caleta (8–15 km).

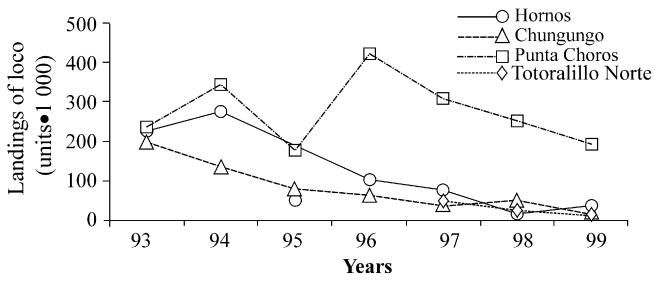

Fig. 5. Landings of locos by caletas during the Benthic Extraction Regime (BER) from 1993 to 1999.

3.4. Spatial distribution of effort for each caleta

In general, analyzing fishing trips by caletas, it was possible to observe an adjustment of fishing effort to the fishing grounds closer to the respective caleta (Fig. 8A–D). Some fishing grounds were exploited by fishermen from more than one caleta. Fishermen used these fishing grounds despite the distance from the base port. By using fishing grounds close to their respective caletas, fishermen may be avoiding competition in most fishing areas (Fig. 8A–D).

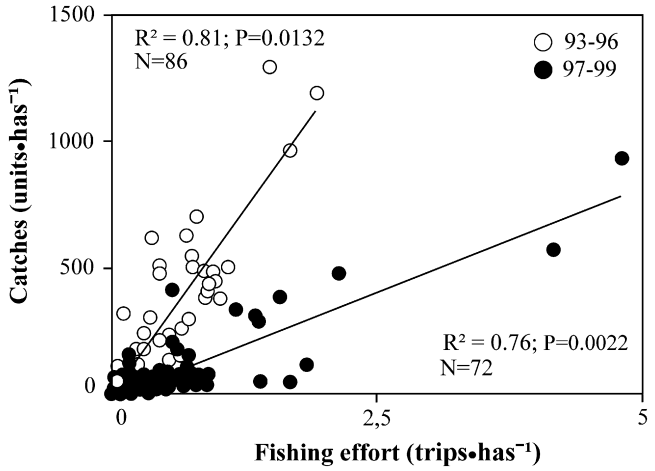

Fig. 6. Relation between numbers of fishing trips and catches made by fishermen of all caletas to the fishing grounds during both analyzed periods.

3.5. Relationship between trips and catches in different fishing grounds

During the period 1993–1996 catches significantly increased with the total kilometers traveled (Fig. 9A), but there were differences between caletas. Fishermen from caleta Hornos had to travel further to obtain the same level of catches as fishermen from Chungungo and Punta Choros. Fishermen from Chungungo showed higher variability in the relationship between catches and fishing trips. The best relationship was observed in Punta Choros, were the highest catches were recorded.

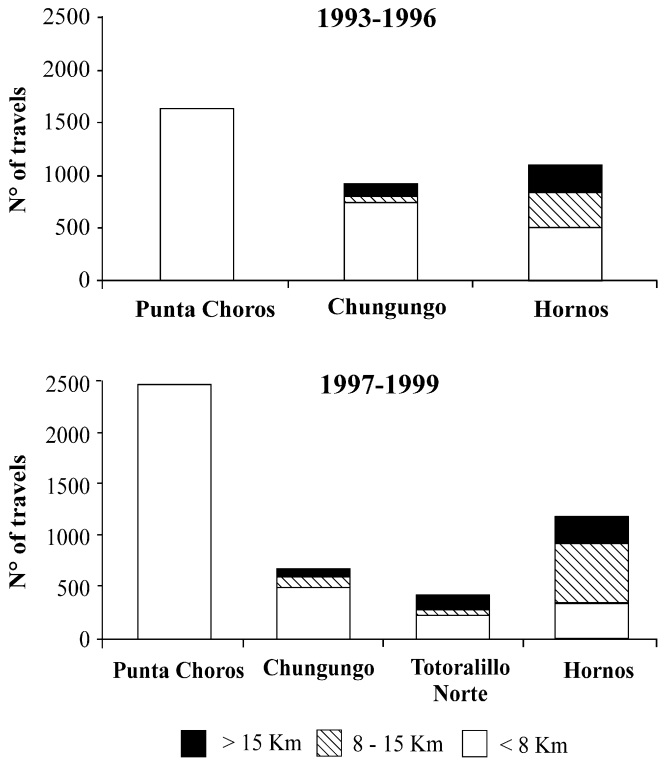

Fig. 7. Distribution of fishing trips made by fishermen in relation to three categories of distance from the respective caletas during the periods 1993–1996 and 1997–1999.

During the period 1997–1999, there was no evident improvement in the efficiency of loco catches for any of the analyzed caletas. All Caletas showed a significant adjustment between catches and the total kilometers traveled to each fishing ground (Fig. 9B). Hornos, Chungungo and Punta Choros showed an increase in the distances traveled, with a decrease in catches compared with the previous period. At Punta Choros, the relationship between kilometers traveled and catches was similar to those in the previous period (Fig. 9B).

We tested if fishermen from Totoralillo Norte achieved a better efficiency in the loco fishery with the installation of the new caleta. For this purpose we compared the relationships between trips and catches for Totoralillo Norte and caleta Hornos. Our analysis showed that there were no differences in the loco's fishery efficiency between fishermen from both caletas. The slope between regressions were parallel ($t_{0.05(2),40} = 1.6149$; $P = 0.114$) and with no differences in the intercept ($t_{0.05(2),41} = 1.9089$; $P = 0.063$). This means that for both caletas the fishermen obtained similar catches with the same effort (kilometers traveled).

4. Discussion

4.1. Totoralillo Norte as new caleta

Our results suggest that the establishment of a permanent caleta from an historical temporary fishing camp did not lead to an increased efficiency of the local loco fishery, neither at caleta Hornos nor at Totoralillo Norte. Thus, other factors may be responsible for the foundation of Totoralillo Norte as new caleta. The traditional loco fishery and the use of temporary and frequently visited fishing camps helped fishermen to obtain important local knowledge about the stock distribution and abundance pattern of different benthic resources. Daw [3] suggests that fishermen may maximize such knowledge by preferring familiar grounds where they can accumulate detailed local knowledge. Possibly, this traditional and accumulated knowledge, and the favorable conditions of Totoralillo Norte (protection against wind and waves and steadily improving road access) motivated fishermen to increase their movements and the use of this fishing camp for fishing loco and other benthic resources.

Interestingly, at the time when fishermen increased the use of Totoralillo Norte as a temporary fishing camp, an economically highly value surf clam, *Mesodesma donacium* (called "macha") appeared at Playa Los Choros (Fig. 2). This new fishery led to a further intensification in the use of Totoralillo Norte as a port by some fishermen from caleta Hornos. The use of Totoralillo Norte as a temporary fishing camp did not improve the efficiency of the loco fishery for those fishermen, but did allow them better access to the macha fishery in Playa Los Choros. This is an important issue, considering that the macha fishery was accessible to fishermen from Totoralillo Norte, but not to those from caleta Hornos, given the respective distances to Playa Los Choros. The case observed at Totoralillo Norte is an illustrative example of a splinter community, the development of which was favored by *M. donacium* as a new species in their resource portfolio [26].

4.2. Characteristics of the study area for the loco fishery

The region of Coquimbo (Region IV) has historically contributed a significant proportion of the national loco landings. This relative contribution dwindled between 1972 and 1988, partly caused by a declining abundance in Region IV and by the increased landings reported in Region X, which fostered an extensive southward migration of fishermen from the region of Coquimbo [23].

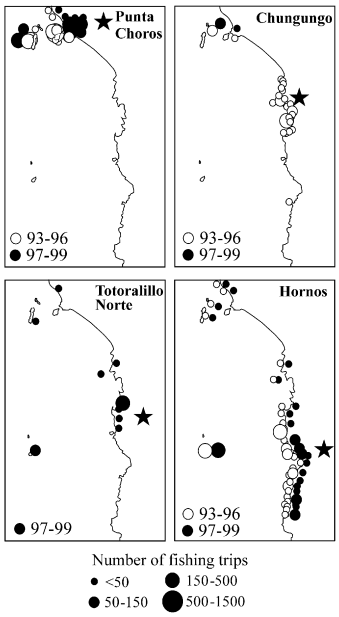

Fig. 8. Distribution of fishing trips made by fishermen of caletas Punta Choros, Chungungo, Totoralillo norte y Hornos, in both analyzed periods. Stars indicate the locations of the respective caletas.

The highest landings of loco have traditionally been obtained in the northern part of the region, specifically at Punta Choros, linked with an upwelling process [19]. Gonzalez et al. [25] reported that Punta Choros acts as a sink zone, trapping larvae that are transported in equatorward currents and accumulated by coastal retention [27]. The high productivity of the Punta Choros zone is also related to geomorphological aspects. This is a coastal area extending to the west, creating a wide platform with several islands (Isla Chungungo, Isla Choros, Isla Damas and Isla Gaviota), which favors larvae retention and settlement. These characteristics contribute to the high productivity at Punta Choros for various benthic resources, with the loco being the most important one.

4.3. Migrations of fishermen and temporary fishing camps

This example of migratory behavior, with the development of simple shelters into a permanent caleta, is a common situation along the Chilean coast. However, there is a lack of reliable documentation of this process by the fishery authorities. These movements are often related to the temporal variability in resource availability. Fisheries of octopus (in northern Chile), red sea urchin (southern Chile) and macha (along the entire Chilean coast) are good examples where resources attract fishermen from other regions of the country, and where temporary fishing camps could result in permanent caletas. In fact, in the extreme north of Chile there are several fishing camps that are in development (as shown in Fig. 1A–D), most of them founded by fishermen from the region of Coquimbo, who moved northwards motivated by the better weather conditions and more pristine stocks.

Changes in fishing effort or temporary migration to places where resources are available is a prevalent feature of artisanal fisheries worldwide, and one that does not fit well with the notion of territorial rights being based on resident populations in shoreline villages [20]. This kind of migration, for fishing seasons, has been documented in Moree, Ghana, where migration and fishing itself has deep historical roots among coastal communities [18]. Changes in spatial effort allocation have also been described in the Galapagos Islands, where many fishermen migrate in pursuit of the

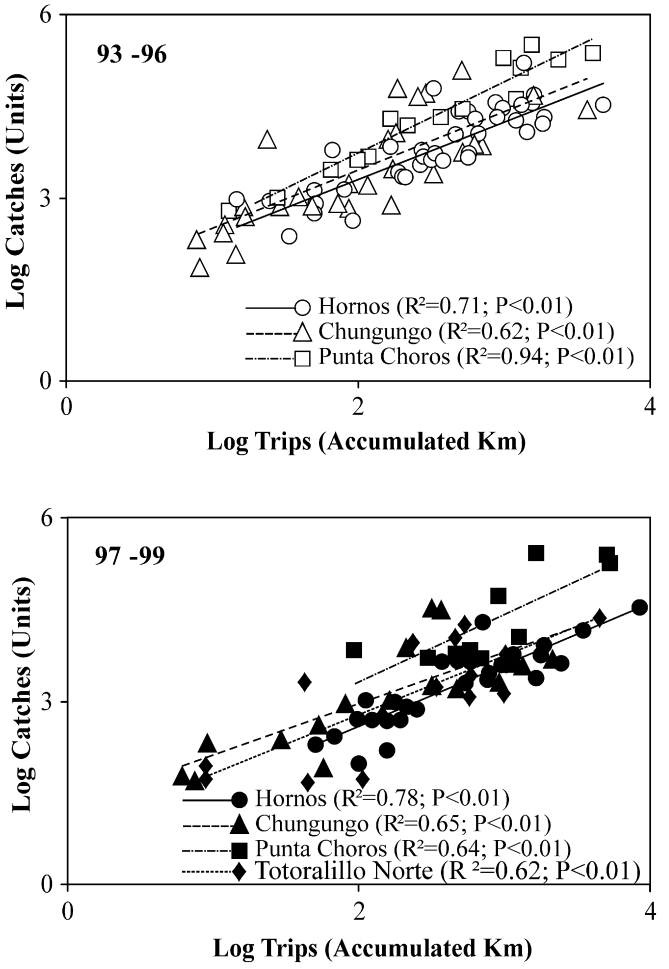

Fig. 9. Relation between fishing trips (accumulated km) and catches of loco during both analyzed periods. Both variables were transformed using Log_{10}.

lucrative fishery of sea cucumbers. In this case, fishermen have migrated to the islands due to the depleted fisheries on the coast and the promise of greater opportunities in the Galapagos [28]. In southeast Asia (Indonesia) migration is also a common practice among fishermen who migrate due to job opportunities on fishing boats and strong fish markets [29]. In this case, economical factors are the main reason for fishermen migration.

Temporary and permanent fishing camps have also been described at Lake Malawi, in Africa, where Allison et al. [30] described short-term and long-term movements. Long-term movements refer to fishermen who have moved from their original homes and have established a new permanent camp elsewhere. In cases of short-term movement, fishermen move in search of fish, but operate from their original homes, only establishing temporary fishing camps.

Migrations and redistribution of spatial effort allocation are thus an important component of the behavior of artisanal fishermen and a traditional livelihood, affecting the ways that people use and manage natural resources [31]. A common reason to move between different places or fishing grounds is related to fluctuations in resource abundance. Seasonal and long-term migration has been an integral part of fisheries in Africa for at least 200 years [18].

4.4. Temporary fishing camps and territorial user rights

In our study, the use of Totoralillo Norte as a temporary fishing camp by some fishermen of caleta Hornos did not improve the

efficiency of the loco fishery for those fishermen, but it allowed them access to the macha fishery in Playa Los Choros. Nevertheless, simultaneously with the development of the macha fishery at Playa Los Choros, the Chilean Subsecretaría de Pesca (Undersecretary of Fisheries) established the regulation for a *de novo* TURF management system, called Management and Exploitation Areas for Benthic Resources (AMERB for the Spanish abbreviation). The AMERB policy was formulated in the early 1990s, but the first AMERB in the study area was formally established in 1997. This spatially explicit tool was essentially created in response to concerns about the sustainability of the loco fishery [19,32,33]. Knowledge of the impending TURF system might have further motivated a group of fishermen to establish themselves at Totoralillo Norte, being relatively close to the temporary macha fishery and a potential future AMERB. However, the AMERB system requires that these areas are located close to the respective caletas. In order to effectively manage their areas and to avoid clandestine harvests, fishermen need to be near their AMERBs, assuming more sedentary habits that, in some cases, disrupt their traditional migrations.

Movements of fishermen and the use of temporary fishing camps are an important strategy to increase efficiency when fishing grounds are located far from the caleta or base port. Temporary fishing camps allow fishermen to get closer to their target resources, but are also important to increase the traditional knowledge on the distribution pattern of other benthic resources and fishes at different fishing grounds. Furthermore, the use of different fishing camps might allow spatial rotation of fishing effort along the coast, allowing resources to recover from temporal extraction seasons.

When conditions in a temporary fishing camp are satisfactory for fishermen (i.e. wind and wave protection, more pristine stocks, road access), it is highly probable that it might develop into a permanent fishing village (or caleta). In Chile, the official recognition of a fishing camp as a permanent (official) caleta by the authorities is necessary (depending of landings and type of land tenure) to obtain funds from the government in developing basic facilities that improve the living conditions of fishermen and their families.

There clearly are some difficulties in accepting that migration and the use of temporary fishing camps may be a legitimate and sustainable strategy to maximize benefits from a fluctuating resource [34]. Movements of fishermen and changes in spatial allocation of fishing effort are factors that need to be considered in the design of any administrative or management scheme. It is important to take into account that mobility and the use of temporary fishing camps has enabled fishermen to respond to the fluctuation of stocks [30], representing an active and ancient opportunistic strategy. As such, it is critical to understand the migration behavior of fishermen and their dynamic allocation of fishing effort before implementing a spatially explicit administrative tool [3–6].

5. Conclusions

Temporary fishing camps are essential components of ancient and contemporary strategies of small scale fisheries. Fishermen actually use temporary fishing camps in order to enhance fishing efficiency or ensure access to resources. Temporary fishing camps are useful when fishing grounds are far from the base port and when spatial redistribution of fishing effort is needed to adjust to local stock fluctuations. However, they require specific administrative tools in order to achieve sustainable fisheries management. An important future task is to design these tools in areas/fisheries where temporary fishing camps are common.

Acknowledgements

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